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**BEFORE THE BOARD OF PATENT APPEALS  
AND INTERFERENCES**

Application Number: 10/663,949  
Filing Date: September 16, 2003  
Appellant(s): RUKA ET AL.

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John P. Musone  
For Appellant

**EXAMINER'S ANSWER**

This is in response to the appeal brief filed 7 December 2006 appealing from the Office action mailed 25 August 2006.

**(1) Real Party in Interest**

A statement identifying by name the real party in interest is contained in the brief.

**(2) Related Appeals and Interferences**

The examiner is not aware of any related appeals, interferences, or judicial proceedings which will directly affect or be directly affected by or have a bearing on the Board's decision in the pending appeal.

**(3) Status of Claims**

The statement of the status of claims contained in the brief is correct.

**(4) Status of Amendments After Final**

The appellant's statement of the status of amendments after final rejection contained in the brief is correct.

**(5) Summary of Claimed Subject Matter**

The summary of claimed subject matter contained in the brief is correct.

**(6) Grounds of Rejection to be Reviewed on Appeal**

The appellant's statement of the grounds of rejection to be reviewed on appeal is correct.

**(7) Claims Appendix**

The copy of the appealed claims contained in the Appendix to the brief is correct.

**(8) Evidence Relied Upon**

*High Temperature Ion Conducting Ceramics*; T.A. Ramanarayanan, S.C. Singhal and E.D. Wachsman; The Electrochemical Society Interface; Summer 2001; Pgs 22-27

Art Unit: 1745

5,589,285	CABLE et al.	12-1996
5,035,962	JENSEN	7-1991

*Processing and Properties of Porous Ni-YSZ Metal/Ceramic Composites; R.M.C.*

Clemmer and S.F. Corbin; Metal/Ceramic Interactions; 2002; Pgs. 231-243

Rare Element Resources Ltd; <http://www.rareelementresources.com/s/Overview.asp>

Answers.com; <http://www.answers.com/topic/rare-earth-element>

INCO company; Inco.com;

<http://www.inco.com/customercentre/msds/pdf/INCOFIBERNickelCoatedGraphiteFiber-USMSDS.pdf>

Periodic Table: Rare Earth; Chemical Elements.com;

<http://www.chemicalelements.com/groups/rareearth.html>

#### **(9) Grounds of Rejection**

The following ground(s) of rejection are applicable to the appealed claims:

***Claim Rejections - 35 USC § 102/103***

The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

Claims 1-4, 9-12 & 15-17 are rejected under 35 U.S.C. 102(b) as anticipated by or, in the alternative, under 35 U.S.C. 103(a) as obvious over Ramanarayanan et al. (*High Temperature Ion Conducting Ceramics*) as evidenced by applicant's known background art.

Ramanarayanan teaches a solid oxide fuel cell with a lanthanum manganite cathode, a yttria-stabilized zirconia electrolyte and an anode of nickel and zirconia (Pg. 23). A bipolar plate is used to connect the cells together forming a fuel cell stack to generate power (Pg. 23-24). The solid oxide fuel cell can be either a planer or tubular type (Fig. 3). Plasma spraying is taught as a cost-effective non-EVD (non-electrochemical vapor deposition) technique for depositing the electrolyte film (Pg. 23, third column). The fuel electrode film is first applied by the EVD technique (Pg. 24, top of first column). Ramanarayanan then goes on to teach the same anode film can be applied by a cost-effective non-EVD deposition technique. Since a cost-effective non-

EVD technique taught by Ramanarayanan in the preceding paragraph is plasma spraying, one skilled in the art at the time of the invention would immediately envision plasma spraying as an alternative technique of applying the fuel electrode film. As admitted by applicant in the Background of Invention, plasma spraying gives a microstructure characterized by accumulated molten particle splats (Pg. 3 of instant application). Furthermore, the electrodes are applied by any of slurry methods, screen printing or plasma spraying (Pg. 24, top col. 3). To establish inherency, the extrinsic evidence must make clear that the missing descriptive matter is necessarily present in the thing described in the reference, and that it would be so recognized by persons of ordinary skill (MPEP 2163.07). As is just shown, the descriptive matter, plasma spraying the fuel electrode, is present in the prior art and it would be recognized by persons of ordinary skill as a method of applying the fuel electrode material.

Regarding claims 9-11, the process of using a nickel graphite mixture to obtain the nickel for the cermet is seen as a product-by-process claim and even though product-by-process claims are limited by and defined by the process, determination of patentability is based on the product itself. The patentability of a product does not depend on its method of production. If the product in the product-by-process claim is the same as or obvious from a product of the prior art, the claim is unpatentable even though the prior product was made by a different process (MPEP 2113). The final product taught by Ramanarayanan is equivalent to the final product as presented in the instant claims and therefore the claims are anticipated.

In the alternative, Ramanarayanan clearly establishes plasma spraying as a cost effective deposition technique and it would be obvious to one skilled in the art to use the less expensive plasma-spraying technique of applying the anode film over the more expensive EVD technique to reduce the production costs of the fuel cell.

***Claim Rejections - 35 USC § 103***

Claims 1-8, 12-18 are rejected under 35 U.S.C. 103(a) as being unpatentable over US Patent 5,589,285 (Cable) as evidenced by applicant's known background art.

Cable teaches a solid oxide fuel cell having a cathode of lanthanum manganite, an electrolyte with zirconia and 8 mole% of yttria, and an anode of nickel and zirconia (7:65-8:35, 10:18-20). The amount of nickel used is at least 60% and no more than 85% and the range for zirconia is more than 15% and less than 40% (16:1-20). The interfacial layer between the electrolyte layer and the anode layer is deposited by plasma spraying (8:30-35). This interfacial layer is substantially made from the anode material. While the reference does not explicitly teach plasma spraying the actual fuel electrode layer, it would be obvious to one skilled in the art at the time of the invention to recognize plasma spraying as a viable option for applying the anode material.

Regarding claims 16-18, a separator connects multiple fuel cells together to form a power generating system (14:44-68). A precursor layer, the interfacial layer, is formed on the fuel side. The layer is preferably 1-50 microns and made from a zirconia composition (8:25-10:18). The solid oxide fuel cell can be tubular in shape (1:55-57)

Claims 5-8 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ramanarayanan et al. (*High Temperature Ion Conducting Ceramics*) in view of Jensen (US Patent 5,035,962).

The teachings of Ramanarayanan as discussed above are incorporated herein. However, Ramanarayanan is silent to the composition of the fuel electrode.

Jensen teaches a fuel electrode for an SOFC having a graded composition structure formed by successively depositing layers of nickel-yttria stabilized zirconia mixtures with different compositions (Col. 3, ll. 6-9). Table 1 (Col. 9) gives the compositions of the layers on a volume basis. In order to convert the volume percentages to weight percentages, the following formula was used:

$$\text{Weight\%}_j = \frac{\text{Vol\%}_j (\text{Vol}_j + \text{Vol}_k) \rho_j}{[\text{Vol\%}_j (\text{Vol}_j + \text{Vol}_k) \rho_j] + \text{Vol\%}_k (\text{Vol}_j + \text{Vol}_k) \rho_k} = \frac{\text{Vol\%}_j \rho_j}{[\text{Vol\%}_j \rho_j + \text{Vol\%}_k \rho_k]}$$

The densities used were obtained from [www.matweb.com](http://www.matweb.com) for yttria stabilized zirconia and nickel. The following table lists the weight percents corresponding the volume percents of Jensen's Table 1.

	Volume percent $\text{ZrO}_2$	Weight percent $\text{ZrO}_2$	Volume percent Ni	Weight percent Ni
Layer 1	70-90	63-87	10-30	13-37
Layer 2	40-60	33-53	40-60	47-67
Layer 3	10-30	7.6-24	70-90	76-92.3

As can be seen from the table Jensen teaches minimums of about 60% Ni and about 15% YSZ (claim 5) and about 70% Ni and about 20% YSZ (claim 6). Jensen also

teaches maximums of about 85% Ni and about 50% YSZ (claim 7) and about 80% Ni and about 30% YSZ. The compositions of the individual layers of the multiple layer graded structure approximate a layer in which the composition is continuously graded from being high in zirconia at the electrolyte interface to being high in nickel at the external surface of the anode and meet the simultaneous requirements of adhesion of the yttria stabilized zirconia electrolyte and adequate electrode electrical conductivity.

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have used the fuel electrode compositions as taught by Jensen in the fuel cell as taught by Ramanarayanan in order to meet the simultaneous requirements of adhesion of the yttria stabilized zirconia electrolyte and adequate electrode electrical conductivity taught by Jensen.

Claims 9-11 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ramanarayanan et al. (*High Temperature Ion Conducting Ceramics*) in view of Clemmer et al. (*Processing and Properties of Porous Ni-YSZ Metal/Ceramic Composites*), as evidenced by INCO, Ltd.

The teachings of Ramanarayanan as discussed above are incorporated herein. Ramanarayanan is silent to at least a portion of nickel in the fuel electrode is obtained from nickel graphite powder.

Clemmer teaches Ni/yttria-stabilized zirconia fuel cell anodes in which Ni-coated graphite particles (55% Ni content; obtained from INCO, Ltd.: Pg. 233) were used as a starting material. Nickel coated graphite particles available from INCO contain either 60

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or 75% ([www.incosp.com](http://www.incosp.com)). Generally, the anodes created from the Ni-coated graphite particles had a lower coefficient of thermal expansion and higher electrical conductivity for a given Ni loading compared to the anodes made of separate Ni and graphite particles. The hybrid structures had intermediate values of coefficient of thermal expansion and electrical conductivity (Abstract).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have used Ni-coated graphite particles as a starting material for Ni/yttria-stabilized zirconia fuel cell anodes as taught by Clemmer in the fuel cell as taught by Ramanarayanan in order to achieve lower coefficient of thermal expansion and higher electrical conductivity for a given Ni loading.

Claims 13 & 14 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ramanarayanan et al. (*High Temperature Ion Conducting Ceramics*).

The teachings of Ramanarayanan as discussed above are incorporated herein.

Ramanarayanan is silent to the fuel electrode having at least 7-mole% yttria in the yttria-stabilized zirconia.

Ramanarayanan teaches that the yttrium oxide dopant in the Ni/YSZ anode serves to stabilize the high temperature cubic phase in zirconia and also generates oxygen vacancies through a defect reaction to create more of the ion conducting species. Nickel may be used as the anode, but the thermal expansion of nickel does not match with that of the electrolyte, YSZ, and nickel may sinter at fuel cell operating temperatures. By forming a skeleton of YSZ around the nickel to form a cermet, the

electrode thermal expansion coefficient is brought closer to that of the electrolyte and thus provides for better adhesion (Pg. 22-24). It has been held that discovering an optimum value of a result effective variable involves only routine skill in the art (MPEP 2144).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to vary the percentage of yttria in the Ni/YSZ anode in order to minimize thermal stress by matching the anode and electrolyte thermal expansion coefficients and to provide better adhesion between the anode and electrolyte.

Claim 18 is rejected under 35 U.S.C. 103(a) as being unpatentable over Ramanarayanan et al. (*High Temperature Ion Conducting Ceramics*) in view of Cable et al. (5,589,285).

The teachings of Ramanarayanan as discussed above are incorporated herein; however, the reference is silent to the precursor layer between electrolyte and fuel electrode containing zirconia.

Cable teaches an SOFC with a cathode containing lanthanum manganate (Col. 7, I 66 – Col. 8, I 2), an electrolyte of yttria-stabilized zirconia (Col. 8, II. 12-14), and an anode containing a nickel powder mixed with zirconia (Col. 10, II. 18-20). Between the electrolyte and anode, an interfacial layer (applicant's precursor layer) containing sulfur tolerant material is disposed (Col. 3, II. 1-3); the interfacial layer may contain Y-doped  $ZrO_2$  (Col. 10, II. 1-4; applicant's zirconia). The thickness of the interfacial layer is

generally 1-100  $\mu\text{m}$ , preferably less than 50  $\mu\text{m}$  (Col. 8, ll. 35-37). The interlayer serves to improve electrical contact between the electrolyte and anode and provides an environment in which the species can interact or react because the interlayer keeps sulfur from the fuel from poisoning the anode, particularly Ni/YSZ cermet anodes (Col. 8, ll. 19-34; Col. 6, ll. 55-63; Col. 18, ll. 23-29).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have included the Y-doped zirconia interlayer as taught by Cable between the anode and the electrolyte of the fuel cell as taught by Ramanarayanan in order to improve electrical contact and provide an environment in which the species can interact or react.

#### **(10) Response to Argument**

(1) Appellant's independent claim 1 comprises a tubular solid oxide fuel cell with an air electrode, an electrolyte formed on a portion of the air electrode and a ceramic-metal fuel electrode having a microstructure characterized by accumulated molten particle splats formed on at least a portion of the electrolyte. Appellant argues the Ramanarayanan reference does not teach the fuel electrode having a microstructure.

This argument is not persuasive for the following reasons:

First, the prior art teaches a fuel electrode (anode) having a thickness of 100-150 microns. This alone constitutes a microstructure (Pg. 24, top of column 1).

Second, the 'characterization by accumulated molten particle splats', is seen as a product-by-process limitation. The final product, a fuel electrode, is not in a molten state and so the accumulation of molten particles is a process of reaching the final fuel electrode product. As such, even though product-by-process claims are limited by and defined by the process, determination of patentability is based on the product itself. The patentability of a product does not depend on its method of production. If the product in the product-by-process claim is the same as or obvious from a product of the prior art, the claim is unpatentable even though the prior product was made by a different process (MPEP 2113). As noted in the rejection, the reference teaches plasma spraying, screen printing, slurry methods and colloidal/electrophoretic deposition as methods of forming the anode. Applicant has not shown that one of the application processes taught by Ramanarayanan does not produce the final product of a fuel electrode with a microstructure. Therefore the final product taught by Ramanarayanan is considered to anticipate the instant claims.

Appellant also argues the prior art does not teach plasma spraying to produce the fuel electrode. First, in response to Appellant's argument that the references fail to show certain features of applicant's invention, it is noted that the features upon which applicant relies (i.e., plasma spraying) are not recited in the rejected claim(s). Although the claims are interpreted in light of the specification, limitations from the specification are not read into the claims. See *In re Van Geuns*, 988 F.2d 1181, 26 USPQ2d 1057 (Fed. Cir. 1993). Second, the Ramanarayanan reference does teach plasma spraying and teaches the method to be a more cost effective method than electrochemical vapor

deposition (EVD) (Pg. 23, bottom col. 3 – Pg. 24, top col. 1). The electrodes are applied by any of slurry methods, screen printing or plasma spraying (Pg. 24, top col. 3).

Appellant argues no parameters for plasma spraying are given in the reference and so one skilled in the art would not know how to plasma spray the fuel electrode. However, it is held that the plasma spraying technique is well known in the art and it would be obvious to one skilled in the art at the time of the invention to use the plasma spraying technique. This position is supported by the Appellant's specification page 15, "Some background information for general plasma spray techniques can be found in US Patent Nos. 3,220,068, 4,049,841, 5,085,742, and 5,426,003, and those skilled in the art will recognize and understand other general plasma spray techniques." The latest published patent listed above 5,426,003 was published on 20 June 1995. So the plasma spraying technique would be well known to one skilled in the art at the time of the invention.

Appellant argues the rare-earth element stabilized zirconia of claim 15 is not taught by the prior art since only yttria stabilized zirconia is taught and yttrium is not considered a rare-earth element according to Chemical Elements.com web page showing the Periodic Table of Rare Earth elements. However, no definition of the rare-earth elements was provided in the instant specification. Yttrium and Scandium are well known rare-earth elements. The following definitions provided by Answers.com show that Yttrium and Scandium are rare-earth elements:

From *Science and Technology Encyclopedia*, The group of 17 chemical elements with atomic numbers 21, 39, and 57–71; the name lanthanides is reserved for the elements 58–71.

From *Britannica Concise Encyclopedia*, Any of a large class of chemical elements including scandium (atomic number 21), yttrium (39), and the 15 elements from 57 (lanthanum) to 71.

From *Columbia University Press*, in chemistry, group of metals including those of the lanthanide series and actinide series, usually yttrium, sometimes scandium and thorium, and rarely zirconium.

From *Wikipedia*, "Rare earth elements" and "rare earth metals" are trivial names sometimes applied to a collection of sixteen chemical elements in the periodic table, namely scandium, yttrium, and fourteen of the fifteen lanthanides (excluding promethium), which naturally occur on the Earth. The former two are included as they tend to occur with the latter in the same ore deposits. Some definitions additionally include the actinides.

From *Rare Element Resources LTD*, The rare-earth elements are the 15 lanthanide-series elements, with atomic numbers 57 through 71, which are in Group IIIA of the Periodic Table. Yttrium (atomic number 39), a Group IIIA transition metal, although not a lanthanide is generally included with the rare-earth elements, as it occurs with them in natural minerals and has similar chemical properties. Also, commonly included with the rare-earth elements because of their similar properties are scandium (atomic number 21) and thorium (atomic number 90).

The claims have been given their broadest reasonable interpretation and in light of the missing definition in the instant specification and using the definitions of rare-earth elements above, Yttrium is a rare-earth element and therefore meets the limitations of instant claim 15.

(2) Appellant argues the motivation for the plasma spraying is not obvious to one skilled in the art. As stated above the instant claims are product-by-process. MPEP 2113 states, "The lack of physical description in a product-by-process claim makes determination of the patentability of the claim more difficult, since in spite of the fact that the claim may recite only process limitations, it is the patentability of the product claimed and not of the recited process steps which must be established. We are therefore of the opinion that when the prior art discloses a product which reasonably appears to be either identical with or only slightly different than a product claimed in a product-by-process claim, a rejection based alternatively on either section 102 or section 103 of the statute is eminently fair and acceptable." Furthermore, the prior art teaches applying the electrodes by any of slurry methods, screen printing or plasma spraying (Pg. 24, top col. 3).

However, in response to Appellant's argument that economics would provide "a motivation...to solve a technical problem, not how to solve the technical problem", the proposed other economic cost saving measures presented in the Appellant's arguments are not taught by the prior art. The economic cost saving technique that is taught by the prior art is plasma spraying. Therefore, the motivation of reducing the manufacturing cost by applying the electrolyte and electrode using plasma spraying is provided by the

prior art of Ramanarayanan. Regarding the technical obstacles required for plasma spraying, as stated above, it is held that the plasma spraying technique is well known in the art would be obvious to one skilled in the art how to use the plasma spraying technique and this position is also supported by the Appellant's specification page 15, "Some background information for general plasma spray techniques can be found in US Patent Nos. 3,220,068, 4,049,841, 5,085,742, and 5,426,003, and those skilled in the art will recognize and understand other general plasma spray techniques." The latest published patent listed above 5,426,003 was published on 20 June 1995. So the plasma spraying technique would be well known to one skilled in the art at the time of the invention.

(3) Appellant argues the prior art of Cable fails to teach a tubular fuel cell. Cable teaches the structure of the fuel cell is tubular in shape (6:13-16). As discussed above, Cable also describes other references teaching tubular fuel cells (1:55-60). Appellant argues Cable teaches away from tubular fuel cells; however, "disclosed examples and preferred embodiments do not constitute a teaching away from a broader disclosure or nonpreferred embodiments." (MPEP 2124 (II)). Cable further teaches applying a substantially fuel electrode (anode) material to the electrolyte using plasma spraying (8:30-35). It would be obvious to one skilled in the art at the time of the invention to use plasma spraying to prepare a catalytic electrode used to produce electricity in a fuel cell and for applying the fuel electrode to keep the production costs to a minimum by using the same method and not having multiple setups.

Appellant argues Cable fails to teach the molar percent of yttria as recited in claims 13 and 14. As pointed to previously, 8-10 mole% yttria is taught in the reference at col. 8, lines 11-15.

Regarding the argument that yttria is not a rare earth element, see the reply listed under the response to the Ramanarayanan arguments for the same topic.

(4) – (7) These paragraphs are directed to the dependent claims and no further arguments are presented other than the secondary references do not suggest the teachings that the Appellant argues are lacking in the primary references.

(8) The Declaration filed on 18 February 2005 under 37 CFR 1.131 has been considered but is ineffective to overcome the Ramanarayanan reference.

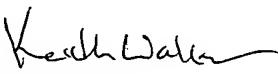
The Ramanarayanan reference is a statutory bar under 35 U.S.C. 102(b) and thus cannot be overcome by an affidavit or declaration under 37 CFR 1.131.

#### **(11) Related Proceeding(s) Appendix**

No decision rendered by a court or the Board is identified by the examiner in the Related Appeals and Interferences section of this examiner's answer.

For the above reasons, it is believed that the rejections should be sustained.

Respectfully submitted,

  
Keith Walker

Conferees:

MARK RUTHKOSKY  
Patrick Ryan

Mark Ruthkosky 3.8.2007

William Krynski

William Krynski 3/8/07

## Overview

When the first rare-earth elements were discovered over 200 years ago, they were thought to be exceedingly rare—hence their group name. In fact, they make up nearly 25 per cent of all the metals in the earth's crust. However, the minerals in which they are naturally concentrated are rare; therefore, it is rare to find large economically mined deposits.

The rare-earth elements are the 15 lanthanide-series elements, with atomic numbers 57 through 71, which are in Group IIIA of the Periodic Table (right). These are lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium. The rare-earth elements are represented by the single square of lanthanum in the main part of the Periodic Table and listed in a separate sub-table below the main groupings.

Yttrium (atomic number 39), a Group IIIA transition metal, although not a lanthanide is generally included with the rare-earth elements, as it occurs with them in natural minerals and has similar chemical properties. Also, commonly included with the rare-earth elements because of their similar properties are scandium (atomic number 21) and thorium (atomic number 90).

Rare-earth elements are classified into two groups: the light or cerium subgroup, comprising the first seven elements (atomic numbers 57-63) with thorium; and the heavy or yttrium subgroup, comprising the elements with atomic numbers 64-71 as well as yttrium and scandium. Despite its low atomic weight, yttrium is categorized with the heavy rare-earth elements because its properties are closer to those of the heavier group than to those of the lighter group.

Information courtesy of University of Tartu (<http://www.ut.ee/>).

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## rare-earth element

### Dictionary



rare-earth element (râr'ûrth')

*n.*

Any of the abundant metallic elements of atomic number 57 through 71. Also called *lanthanide*.

[So called because they were originally thought to be rare.]

### Science and Technology Encyclopedia

#### Rare-earth elements

The group of 17 chemical elements with atomic numbers 21, 39, and 57-71; the name lanthanides is reserved for the elements 58-71. The name rare earths is a misnomer, because they are neither rare nor earths. *See also* Actinide elements; Lanthanide contraction; Periodic table.

Most of the early uses of the rare earths took advantage of their common properties and were centered principally in the glass, ceramic, lighting, and metallurgical industries. Today these applications use a very substantial amount of the mixed rare earths just as they are obtained from the minerals, although sometimes these mixtures are supplemented by the addition of extra cerium or have some of their lanthanum and cerium fractions removed.

The elements exhibit very complex spectra, and the mixed oxides, when heated, give off an intense white light which resembles sunlight, a property finding application in cored carbon arcs, such as those employed in the movie industry.

The rare-earth metals have a great affinity for the nonmetallic elements, as, for example, hydrogen, carbon, nitrogen, oxygen, sulfur, phosphorus, and the halides. Considerable amounts of the mixed rare earths are reduced to metals, such as misch metal, and these alloys are used in the metallurgical industry. Alloys made of cerium and the mixed rare earths are used in the manufacture of lighter flints. Rare earths are also used in the petroleum industry as catalysts. Yttrium aluminum garnets (YAG) are used in the jewelry trade as artificial diamonds.

Although the rare earths are widely distributed in nature, they generally occur in low concentrations. They are found in high concentrations as mixtures in a number of minerals. The relative abundance of the different rare earths in various rocks, geological formations, and the stars is of great interest to the geophysicist, astrophysicist, and cosmologist.

The rare-earth elements are metals possessing distinct individual properties. Many of the properties of the rare-earth metals and alloys are quite sensitive to temperature and pressure. They are also different when measured along different crystal axes of the metal; for example, electrical conductivity, elastic constants, and so on. The rare earths form organic salts with certain organic chelate compounds. These chelates, which have replaced some of the water around the ions, enhance the differences in properties among the individual rare earths. Advantage is taken of this technique in the modern ion-exchange methods of separation. *See also* Chelation; Ion exchange; Transition elements.

## rare earth metal

Any of a large class of chemical elements including scandium (atomic number 21), yttrium (39), and the 15 elements from 57 (lanthanum) to 71 (see lanthanides). The rare earths themselves are pure or mixed oxides of these metals, originally thought to be quite scarce; however, cerium, the most plentiful, is three times as abundant as lead in the Earth's crust. The metals never occur free, and the pure oxides never occur in minerals. These metals are similar chemically because their atomic structures are generally similar; all form compounds in which they have valence 3, including stable oxides, carbides, and borides.

For more information on rare earth metal, visit [Britannica.com](#).

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## Encyclopedia

rare-earth metals, in chemistry, group of metals including those of the lanthanide series and actinide series, usually yttrium, sometimes scandium and thorium, and rarely zirconium. Promethium, which is not found in nature, is not usually considered a rare-earth metal. The metals usually occur together in minerals as their oxides (rare earths) and are somewhat difficult to separate because of their chemical similarity. A subgroup of the rare-earth metals, consisting of those with atomic numbers between 57 and 63 and ytterbium, is often called the cerium metals. Misch metal is an alloy of the cerium metals often used in lighter flints, in alloys with other metals (especially magnesium), and to remove residual gases in the manufacture of vacuum tubes. Individual metals may be isolated as their compounds by ion exchange methods, solvent extraction, or fractional crystallization, and chemically or electrolytically reduced to the pure metal. Uses are discussed in articles on individual elements.

## Bibliography

See F. H. Spedding and A. H. Daane, ed., *The Rare Earths* (1961, repr. 1971); E. C. Subbarao and W. E. Wallace, ed., *Science and Technology of Rare Earth Metals* (1980).

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## WordNet



*Note: click on a word meaning below to see its connections and related words.*

The noun rare-earth element has one meaning:

Meaning #1: any element of the lanthanide series (atomic numbers 57 through 71)

Synonyms: rare earth, lanthanoid, lanthanide, lanthanon

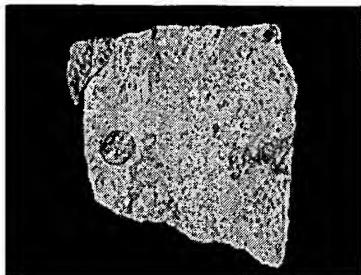
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## Wikipedia



## rare earth element

*"Rare earth" redirects here, for other uses, see [rare earth \(disambiguation\)](#).*



Rare earth ore

"Rare earth elements" and "rare earth metals" are trivial names sometimes applied to a collection of sixteen chemical elements in the periodic table, namely scandium, yttrium, and fourteen of the fifteen lanthanides (excluding promethium), which naturally occur on the Earth. The former two are included as they tend to occur with the latter in the same ore deposits. Some definitions additionally include the actinides.

"Earth" is an obsolete term for oxide. At the time of their discovery, earths of these elements were believed to be scarce in abundance as minerals. However, the term "rare earth" is now deprecated by IUPAC, as these elements are in fact relatively abundant in the Earth's crust; the most abundant, cerium, at 68 parts per million, is the 25th most abundant element in the crust, more common than lead, while even the least abundant "rare" earth element, lutetium, is 200 times more abundant than gold.

The principal economic sources of rare earth elements are the minerals bastnasite, monazite, and loparite and the lateritic ion-adsorption clays. Despite their relative abundance, however, these are more difficult to mine and extract than the sources of transition metals (due in part to their very similar chemical properties), making them relatively expensive.

The following abbreviations are often used:

- REE = rare earth elements
- LREE = light rare earth elements (La-Sm)
- HREE = heavy rare earth elements (Eu-Lu)

For more details of the properties and uses of these elements, refer to the lanthanides article.

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145 King Street West, Suite 1500  
Toronto, Ontario, Canada M5H 4B7  
TEL: 1-416-361-7537 FAX: 1-416-361-7659

**USA:**  
681 Lawlins Road  
Wyckoff, NJ 07481 USA  
TEL: 1-201-848-1012 FAX: 1-201-848-1022

**EUROPE:**  
Clydach Refinery  
Swansea, SA6 5QR, Wales  
United Kingdom  
TEL: 44-1792-841281 FAX: 44-1792-845372

**JAPAN:**  
TT-2 Bldg.  
3-8-1, Nihonbashi-Ningyocho, Chuo-ku,  
Tokyo 103-0013, Japan  
TEL: 81-3-5652-1831 FAX: 81-3-5652-1841

**ASIA:**  
15th Floor, Wilson House  
19-27 Wyndham Street Central, Hong Kong  
TEL: 852-2521-2333 FAX: 852-2810-1965  
  
Rm 411  
Shanghai Dynasty Business Centre  
No. 457 Wu Lu Mu Qi North Road  
Shanghai 200040, P.R.China  
TEL: 86-21-62492100 FAX: 86-21-6249-1712